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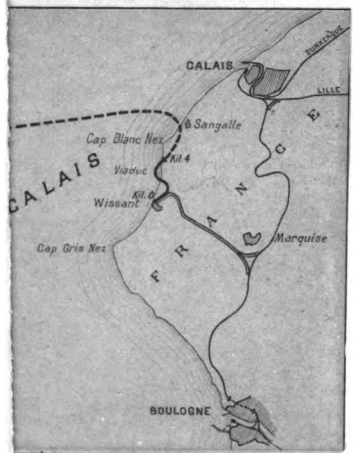
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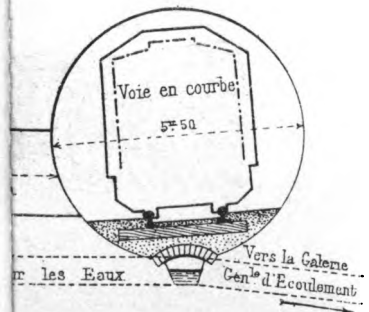
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THE CHANNEL TUNNEL



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THE CHANNEL TUNNEL

BY

ALBERT SARTIAUX

CHIEF ENGINEER FOR ROADS AND BRIDGES
GENERAL MANAGER OF THE NORTHERN RAILWAY OF FRANCE

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THE CHANNEL TUNNEL.

THE serious events which have occurred lately show clearly how important it is for Great Britain and France to be on friendly terms.

The policy that has been successful in suppressing Colonial causes for distrust and conflict show plainly the interest both countries have in realizing an "Entente" to maintain the equilibrium between the Powers of Europe and to prevent it from being broken to the detriment of either country.

As a result of these friendly relations, attention has been drawn to the great importance, from a political, economical, and even a military point of view, of a connection between the two countries otherwise than by crossing the sea. On both sides of the Straits the daily and periodical Press, political men, men of science, Economists, and Engineers are again taking up the question that has been dormant for more than twenty years of a submarine tunnel.

It will not perhaps be useless to summarize the principal points of view from which this question can be regarded.

I.

The original idea of such a connection between France and England is already more than a hundred years old. It was, in fact, in 1802 that the first project of a submarine tunnel was presented to Bonaparte by a mining Engineer of the name of Mathieu.¹

¹ M. de Lapparent, whose name will be frequently mentioned further on and who was one of the principal actors in the active period of preparation of the tunnel from 1877 to 1883, recalled this and many other facts, amongst personal souvenirs, in an article full of deep and witty thoughts, recently published in *Mois littéraire et pittoresque* (Paris, May, 1906).

It was then a question of the mails only, and, as the journey across in a carriage would have been very long, and the problem of air and light seemed difficult to solve in a satisfactory way, Mathieu divided his tunnel into two parts, each of about 10 miles in length, and both opening on to the submarine bank of Varnes, situated nearly in the middle of the Straits. This bank, which is only submerged about 49 feet, was to be raised by strong embankments and transformed into a large and artificial island, on which an international town was to be built, with a harbour of refuge situated between the Channel and the North Sea.

In each part of the tunnel a paved way would have been laid down, lighted by oil lamps, and ventilated by shafts emerging from the water into the open air. This scheme had on the whole no result ; it was based on no serious geological study, and the ways of setting about it were not sufficiently examined. It is interesting to remember, however, that in artificially re-establishing this land communication which existed at the beginning of the present geological period, this project had already appeared as one consequence of the understanding that followed the peace restored by the treaty of Amiens—as one of the means and aims of the “Entente Cordiale,” so necessary to the peace of the world at a time when the equilibrium of European Powers seemed disturbed in the interest of France, and the difficulties were therefore greater.

The great English statesman Fox considered it one of the most efficacious means of realizing the bringing of the two nations together, and, when he discussed the question with the First Consul, the latter is said to have exclaimed : “ Oh ! it is one of the great things we could do together.”

This project was followed by many others, belonging more or less to the domain of fancy—ferry-boats, bridges, submerged tubes, etc., etc.—but all bearing witness to the interest that was already attached at that time to the idea

of putting England in direct land communication with the Continent.

It was only towards the middle of the nineteenth century that Thomé de Gamond presented a project for a tunnel under the Channel, which began to have a scientific aspect.

Thomé de Gamond (1807-1875), hydrographic and mining engineer, military officer, LL.D., and M.D., dedicated his life and fortune to finding out the solution of this problem.

He was an old pupil of Water Staat's, the Waterworks Engineer at Brussels, where he had finished his studies; his mind was soon turned to hydrographic works, and it was during the exploration of the coast of the Channel that the first idea struck him of a means of communication between France and England. All imaginable conceptions were successively considered and published by him: a submerged tunnel constructed with metallic tubes fixed one into the other as telescope tubes (1834 project); a submerged tunnel represented by a submarine arch of concrete at the bottom of the sea (1835 project, called the hydraulic shield); a ferry-boat floating on the Straits and connecting with the cliffs at both sides by means of hydraulic masonry (1837 project); an isthmus of Dover artificially established by the immersion at the bottom of the Channel of blocks of concrete with three passages for navigation (1840); lastly, a submarine tunnel similar to the one of 1875. Thomé de Gamond studied all these projects with the zeal and faith that characterized him, and the first precise geological information about the nature of the bottom of the Straits is owing to him, information collected only by hard work during his successive exploring journeys, namely, the hydrographic campaign of 1833 to verify the marine soundings between Calais and Dover on a line of some 25 miles in length, the geological exploring campaign of 1838-1839 also in the Straits. New investigations of the same sort were renewed from year to year from 1851 to 1855, often at the peril of his life, for he had

the temerity, in order to collect samples of submarine clay, to let himself down to the bottom of the sea at a depth of 108 feet without any diving apparatus, fastened only to a rope, with bags of pebbles weighing 160 pounds as ballast, and assisted merely by a pilot and a few sailors from Boulogne, and his daughter, who always accompanied him, watching these proceedings with an anxious eye.

In 1856 Thomé de Gamond presented a project to Napoleon III for a tunnel under the Channel, but which was not even in his own mind a final one, for ten years later he was obliged to begin over again, and in concluding his work he said: "I have carried my studies to the limit of my personal powers. This work must now be taken up by other intellects well skilled in the physiology of rocks and in the working of subterranean strata."

His appeal was not in vain. The various organs of the European Press from 1857 to 1858 successively gave accounts of his works. About the same date the help of three renowned English Engineers of the time, Isambard Brunel, Joseph Locke, and Robert Stephenson, was assured to him.

Being presented at the same time to H.M. the Queen of England and Prince Albert, his project was received "with marked favour," says one of Gamond's biographers. Thus encouraged, he improved his first project and sent completely revised plans to the Universal Exhibition of 1867. At last in 1869 an Anglo-French Committee selected by him was formed partly in Paris and partly in London, so that Thomé de Gamond's scheme following the author's wish "had, in short, been undertaken by several other intellects." The aim of the Anglo-French Committee was to work on each side of the Straits for the forming of Companies, and to obtain the concession for the proposed work.

Here begins the diplomatic phase of the project, and it is not without interest to condense its principal facts, because the account of the diplomatic negotiations exchanged between

France and Great Britain show with what minuteness the two Governments had studied the project, and with what precautions and thought they had at last arrived at a complete diplomatic harmony, in solving questions quite usual for a Continental power like France, but quite new for England, and which were raised by the proposed creation of an international railway, complicated by the length of the proposed work, and by the novel fact that it would penetrate into regions in which territorial rights had never yet had to be considered.

It was in April, 1870, that the first communications were exchanged between France and England; at this date, at the request of the Anglo-French Committee, the French Ambassador asked the British Government if it were disposed to admit the principle of the enterprise, and, consequently, to regulate by a diplomatic convention the conditions on which the construction and working of the new Railway would be authorized. (The Marquis de la Valette to Lord Clarendon, April 15th, 1870.)

Lord Clarendon's first reply was that England could only guarantee the honesty and good faith of the British subjects interested in the matter, but that facts were still missing to enable him to decide on the possibility of executing such an enormous enterprise, and on the expenses of its execution.

M. de la Valette then insisted on obtaining a more categorical answer, but before a reply could reach him the war with Germany put an end for the time to the negotiations, which were taken up again, however, as soon as peace was re-established.

Indeed, by November 30th, 1871, M. de Rémusat, the Minister for Foreign Affairs in Paris, renewed the question which had already been put before the British Government by M. de la Valette. Meantime the Anglo-French Committee were moving on their side, and the Secretary of State for Foreign Affairs, Lord Granville, was not taken

unawares. The Board of Trade on being consulted gave a favourable opinion under certain conditions, and on June 24th, 1872, Lord Lyons, the British Ambassador in Paris, acting on instructions from London, sent to M. de Rémusat a very explicit note, in which he gave a formal adhesion to the principle of the tunnel projected between France and England, with certain reservations, bearing solely on the conditions of the concession, and the execution of the submarine railway.

These reservations, far from lessening the acceptance of the principle, emphasized the spirit in which it was given. The British Government thought that the technical difficulties of the undertaking might be overcome, but wondered if it could be arrived at financially without the aid of the State. It declared itself against the concession being granted for ever to a private Company, and was of the opinion that the two Governments should agree on terms for redeeming the concession.

In the following year a still more formal adhesion, if possible, was given to the principle of the tunnel, and it is worthy of notice that this time it was through the instigation of the Board of Trade itself, and by the initiative of Lord Granville that the question was again taken up. On July 23rd his Lordship thought necessary to indicate to Lord Lyons how he should reply, were he questioned as to the dispositions of England on the subject of the Tunnel project. In that case the Ambassador should answer that Her Majesty's Government would see with satisfaction any improvement in the communications between England and the Continent, and that it would be happy in consequence, to hear of the success of an undertaking destined to connect the British railways with the Continental railway system.

The British Government, opposed as it was to the principle of monopoly, did not see any objection to a concession being granted to the promoters of the enterprise, under the ordinary

conditions of contracts of this character in France, provided that the conditions of a lease with terms of redemption counteracted the establishment of a monopoly prejudicial to public interest.

It was obvious that it was not only the question of principle which had been agreed to, but that the British Government was already considering the conditions under which it would subordinate the concession of the line.

At last, on July 25th, 1873, Lord Lyons, who always followed his instructions strictly to the letter, asked if he should spontaneously complete by a memorandum the preceding explanations which he had given to the French Government.

The reply of the British Cabinet was in the affirmative, and the memorandum was handed to our Government by Lord Lyons.

Let us add that a note at the foot of a page of the Blue Book containing Lord Granville's letter of July 25th explains the steps taken by the British Minister for Foreign Affairs, and emphasizes the insistence with which he gave his adhesion to the Tunnel project, and his encouragement to the undertaking.

In the presence of such a complete agreement the French Government saw no more obstacles to the granting the concession for the railway under the Channel.

However, a Conservative ministry had just succeeded in England to that of Mr. Gladstone which had shown itself so broad-minded in the study of the project and which had a really prophetic foresight of the future. The French Government on October 27th, 1874, that is to say, almost on the eve of the granting of the concession, communicated to the British Government through the medium of Count de Jarnac, our Ambassador in London, the very terms of the Act by which it proposed to grant the concession. In the reply, which was under the form of

a written note sent to the said Count on December 24th, 1874, Lord Derby, Minister for Foreign Affairs, gave his adhesion to all the conditions of the draft ; he recognized the right of both countries to establish works of defence at the extremities of the tunnel, without mentioning, however, on whom the expenses would devolve ; he stipulated the power of interrupting the traffic, reserving the question of knowing if the Governments would have the right of using this faculty without giving rise to a claim for indemnity on the part of the Company. The letter concluded by complete approbation of the course that the French Government proposed pursuing.

Both Governments, moreover, thought it advisable to arrange the terms of their agreement by means of an international Commission of eight members, four named by the British, and four by the French Government. This Commission closed its work by the drawing up of a protocol signed by the representatives of both countries (May 30th, 1876),¹ and which, in case the question were taken up again, would only need to be ratified by the French and English Parliaments in order to conclude the affair between the two countries from a diplomatic point of view.

It was more than a year before that date that a Company had been formed in France with the view of obtaining from the Government the grant of a submarine railway to England. It was, in fact, on February 1st, 1875, that the French Company,² which is still in existence and ready at the first favourable opportunity to resume its labours, was formed, to whom the concession was granted.

The new Company, presided over by M. Michel Chevalier,

¹ See Appendix.

² The Committee representing this Company is now composed of the following members :—M. A. D. Vernes, President ; M. G. Griolet, Vice-President ; MM. R. Duval, Ch. Nemachy, N. Johnston, Jouet-Pastré, P. Leroy-Beaulieu, G. Mirabaud, M. R. Duval, P. Schneider, J. Caillaux, A. Sartiaux ; M. Breton, Engineer and Manager.

the Free Trade apostle and inspirer of the commercial treaties of 1860, included such men as Lavelley, the renowned Engineer who had just distinguished himself by dredging the Suez Canal, and also Fernand - Raoul Duval, Léon Say, who would later succeed Michel Chevalier in the Presidency, Paul Leroy-Beaulieu, etc., etc.

The aim of the Company was thus defined by its statutes :

(1) To carry on the studies destined to confirm the possibility of completing a tunnel under the Straits in order to create a land communication between France and England.

(2) To obtain from the French Government the grant of a railway starting at a given point on the Northern Railway of France, between Boulogne and Calais, and penetrating under the sea in the direction of England.

(3) In case of success, to definitely form a Company having for its object the execution and commercial working of the tunnel and also of the railway destined to effect the junction between the English and French lines.

The capital of this Company was fixed at two million francs (£80,000) divided into 400 shares of 5000 francs (£200) each, of which 200 were taken by the Northern Railway Company of France, 100 by MM. de Rothschild Brothers, and 100 by various others.

The law of August 2nd, 1875, approved the agreement made on the same date by the Minister of Public Works with this Company, and granted it the concession of the line thus defined : " Railway starting at a given point on the Boulogne and Calais line, running under the sea towards a similar line starting from the English coast in the direction of the French shore."

The concession was granted with neither subsidy nor guarantee of interest, on a lease of 99 years from the time of the beginning of the working of the submarine railway, the State binding itself not to concede such right during a period of 30 years, reckoned from the same time, to any

other railway starting from the shore, and running under the sea in the direction of England.

The concession was definitely settled and the railway declared of public utility by the act of Parliament granting the concession.

The Company undertook to declare in the course of from five to eight years if it intended to adhere to the concession. It also bound itself to carry out to the amount of at least two million francs, the preparatory works of all sorts, such as investigations, shafts, galleries, soundings, etc., deemed necessary in order to satisfy the Administration and the Company on the technical points of the undertaking ; also the possibility of completing it with reasonable chances of success. Besides that, the concessionaires undertook to enter into relations with an English Company in order to carry out the submarine railway starting from the English shore in the direction of France, so that they might carry out and work in common accord the whole of the international railway.

The French Tunnel Company has fulfilled all its duties. It has spent more than two million francs on preparatory works, shafts, soundings, and galleries ; we shall refer to this subject later on. It has also fulfilled conditions the accomplishment of which have rendered the concession definite. It continues to pay the French Government the fees for control specified in the convention. All the works and installations it has carried out are preserved in a satisfactory state, so that at any time definite working could be undertaken immediately, if the difficulties and opposition that arose on the English side twenty years ago in such an unexpected manner were removed.

The fact is the results of the studies were from a technical point of view quite as favourable and conclusive in England as in France, but matters with regard to legislation and administration, did not move with the same facility as in our country.

Administratively there had been not less than three Companies dealing with the tunnel question. They were the following in chronological order :—

(1) The Channel Tunnel Company, presided over by Lord Richard Grosvenor, with Sir John Hawkshaw and Mr. Brunlees as engineers.

(2) The South-Eastern Railway Company, for which the tunnel would only be an extension of its line between Dover and London.

(3) The Submarine Railway Company.

These three Companies worked in common accord until they amalgamated. The first had only a nominal existence. Incorporated on January 15th, 1872, it lost the power obtained for one year only by a Bill of Parliament on August 2nd, 1875, by letting that year elapse without taking any steps towards using those powers, which enabled them to acquire by compulsory sale the lands necessary for beginning the works in the parish of St. Margaret-at-Cliff in Kent. These powers were in fact the only ones granted by this Bill, the English Government having reserved its liberty of action with regard to the concession of the line itself. Let us add that the works of this Company were confined to the sinking of a shaft and to a few yards of gallery at St. Margaret.

The second Company which dealt with the tunnel, viz. the South-Eastern Railway Company, took on the contrary most important steps. A Bill passed July 16th, 1874, authorized this Company to take part in the widening of Boulogne harbour, and at the same time "to spend a sum of one million francs (£40,000) towards the cost of any soundings, and of any borings, shafts, galleries, or other works in connection with the construction of a tunnel under the English Channel."

An Act passed in 1881 also gave it the powers necessary to proceed with the compulsory purchase. This Bill imposed

among other things the following obligation :—" In case the construction of a tunnel between England and France shall hereafter be authorized by Parliament, the Company must accept all conditions, either those mentioned in the Protocol agreed on by the International Commission of 1876, or any other condition it may please Her Majesty in Council to impose in consequence of any new arrangement with the French Government." From a legal point of view the situation of the South-Eastern Company was identical with the Channel Tunnel Company. In fact, the Bill of 1881 ended by these words : " The passing of this Act shall not be deemed to give to the Company any right or claim with respect to the construction of any tunnel between France and England."

Furnished with these powers the South-Eastern Railway Company communicated with the French Company, and whilst the Channel Tunnel Company abandoned its works at St. Margaret-at-Cliff the new Company undertook other works at Abbots Cliff, between Dover and Folkestone, the results of which were not less favourable than those executed in France.

It was at that period that the Submarine Railway Company was founded in England (December 8th, 1881) with a capital of 6,250,000 francs (£250,000), having for its object the acquisition of the rights of the South-Eastern and Channel Tunnel Companies, of undertaking experimental works, of obtaining more absolute power from Parliament, and of subsequently forming a definitive Company for the construction.

The acquiring of the rights of the South-Eastern Company by the Submarine Railway became an accomplished fact July 6th, 1882 ; and thus in possession of the previous rights of the parent Company, in what concerns the tunnel, the new Company continued the works already begun by the former with great vigour, and towards the end of 1882 at the foot

of Shakespeare's Cliff at Dover there was a gallery of $1\frac{1}{4}$ miles, about 1,700 yards being under the sea.¹

Such was the condition of the works when they were interrupted by the opposition that suddenly arose in England and manifested itself: first, by an article in the *Times*, then by a pamphlet² that caused a great sensation, in which the author, richly gifted with delightful English humour, pictured with much wit Dover invaded one fine night on the arrival of an excursion train by a band of trippers, imposing in number, but of most peaceable appearance—a sort of Cook's caravan. These tourists quietly went to sleep in the rooms they had previously engaged at the hotels. Then suddenly during the night, at a given signal, rushing out of bed and furtively creeping towards the harbour, they seized hold of a stock of rifles brought by two steamers. That decided the fate of the great nation: Dover taken, the garrison butchered, and the tunnel meanwhile incessantly vomiting men of all arms; and London invaded! England

¹ A magazine of that time gives the following account of a visit paid in 1882 to the submarine gallery by a number of engineers with their families:—"A railway ran along the gallery, which was magnificently lighted by electric lamps, Swan's system. The visitors were conducted twenty at a time to the end on a sort of trolley or benches on wheels drawn by a couple of men. In the centre of the tunnel a kind of saloon, decorated with flowers and evergreens, was arranged, and, on a large table, glasses and biscuits, etc., were spread for the inevitable luncheon. There was no infiltration of water in any part. In the places where several small fissures and slight oozings had appeared during the boring operations, a shield in sheet iron had been applied against the wall by the engineer, following all the circumference of the gallery and making it completely watertight. There they were as in a drawing-room, and the ladies having descended in all the glories of silks and lace and feathers were astonished to find themselves as immaculate on their return as at the beginning of their trip. The atmosphere in the tunnel was not less pure, but even fresher than outside, thanks to the compressed air machine, which, having acted on the excavator at the beginning of the cutting, released its cooled air in the centre of the tunnel."

² "L'agitation Anglaise contre le tunnel de la Manche," par G. Valbert.—*Revue des Deux Mondes*, 1st June, 1882.

raided and conquered! Under the pen of the imaginative chronicler all this was the work of a few hours!

Then the Egyptian question, now solved, offered at that time a splendid opportunity to traditional alarmists of frightening the timid. The Conservative party took the lead of the opposition by presenting the Government with a petition against the tunnel signed by the representatives of old English families such as the Dukes of Wellington and Marlborough, lords, earls, baronets, admirals, generals, bishops, a crowd of clergymen, poets, philosophers, Herbert Spencer in person, the poet and thinker Robert Browning, the learned Professor Huxley, etc.

At last the final blow was given to the idea of a tunnel in a pamphlet by Admiral Lord Dunsany. So when, at the beginning of 1883, the two Companies of the Channel Tunnel Railway and the Submarine Railway both asked the British Parliament for power to definitely undertake the work of the Channel tunnel, the two Bills were not supported by the Government, and in consequence were withdrawn from the order of the day without even having been discussed.

From this period the Companies interested, vainly attempted to influence Parliament in favour of their project, and indeed once 76 votes were only required to enable a new Bill, introduced in 1887, to be adopted by the House of Commons, but this went no further, and the scheme was once again rejected in 1888.

Since then the Companies authorized to begin the preparatory works on the English side, thought only of securing the preservation of their rights, and the Submarine Railway Company amalgamated in 1886 with the Channel Tunnel Company, as it had already amalgamated in 1882 with the South-Eastern Railway Company, whose rights to the construction of the tunnel it had acquired.

This short historical account would be incomplete did it not recall several other schemes that were brought forward

just when England put its veto on the construction of the tunnel. This opposition, far from discouraging the men who were animated by the great idea of uniting France to England by means of a communication independent of the sea, turned the minds of inventors towards other systems in connection with which it would be impossible to arouse in the English mind even the shadow of a doubt as to their national security. It was in this manner that for twenty years studies of schemes prior to that of the tunnel have been considered and new projects brought forward.

These projects can be classed in three different categories :

(1) A bridge over the channel sufficiently raised above high-water level to allow passage for ships.

(2) A submerged bridge to be used as a road for a transporter wagon that would carry the trains.

(3) Ferry-boats arranged so as to carry the trains.

The project of a bridge over the Channel has been the object of most profound study, and in 1892 a Company founded under the name of the Channel Bridge and Railway Co., Limited, published a report on the question. In the final plans the course adopted crossed the Straits at their narrowest part ($20\frac{1}{2}$ miles) in a straight line from the South Foreland to Sangatte, and it comprised 72 piers in the sea, giving 73 spans alternatively 433 and 541 yards in length. The average depth of the Straits at lowest tide being 36 metres, the deepest piles would have to be raised to a height of 51 metres (165 feet) from the bottom of the sea. They would have been used as a support for the metallic columns destined to bear the steel girders, the under side of which would have been raised to a uniform height of 54 metres (174 feet) above high water.

From a technical point of view this was unquestionably a magnificent scheme, at any rate as regards the metallic part of the work. Its realization would mean certain triumph for the Engineers, but it raised extremely grave objections,

not only technical, but administrative, political, diplomatic, and financial.

Technically, the fixing of piers at a depth exceeding 54 yards in certain places below high-water level would raise insurmountable difficulties, and even in the present state of science it is not easy to foresee a solution of this difficulty.

Supposing it were possible to succeed in placing the enormous caissons and masonry to form the submerged foundation on the sites assigned for the piers, these foundations would, in direction as well as rapidity, modify the already very swift currents of the tide in such a way as to render them in the Straits probably as dangerous to navigation as the works themselves would be.

Financially there was more to be feared : the authors themselves estimate the cost of construction at not less than 860,000,000 francs (£34,400,000), so that £40,000,000 at least must be reckoned on, and the cost of maintenance would be in proportion. The authors of the scheme fix the expenses of repainting alone at £40,000 a year, counting from the fourth year, the whole of the gigantic steel construction having to be entirely repainted every four years. On the other hand, they estimate that after the twenty-fifth year of the running of the Railway the rivets should be replaced, and by taking the number of five million rivets to be replaced per annum on a total of 200 millions they fix the annual cost under that head at £52,000. Lastly, they foresee yet another expense of £48,000 for the gradual renovation—always counting from the twenty-fifth year of the running of the line—of a certain number of secondary things, such as beams, girders, superstructure, etc., etc. By this it will be seen that after 25 years the total of these different expenses for maintenance would amount to £140,000. To be added to that are still all the expenses (estimated at £20,000 a year) for the keeping in repair of the lighting apparatus destined to warn navigators of the presence of the piers of the bridge, say a total sum of from £160,000

to £200,000 a year for the general upkeep, and that estimated only approximately. As at least the same amount must also be reckoned for interest and amortisation of the capital, it makes an annual cost of £200,000 at the outset—of £400,000 at the end of a few years from the time when the work is completed. Finally, if all the difficulties could be overcome, there still remains the great objection that would be raised by navigators on account of the impediment caused by the piers of the bridge. These piers at a distance of 540 yards one from the other would probably not seriously inconvenience steamers in clear, calm weather. They would, however, disturb the currents of the Straits and thereby create new sandbanks. The cost of lighting and sounding apparatus to warn navigators of the presence of the piers must then also be faced, also the expense of setting up buoys in the neighbourhood of the sandbanks.

But the presence of these piers would certainly involve much more serious inconvenience to sailing vessels, and there are still many in existence. Everyone must have noticed after a few days of south-west or north-east wind parallel to the general direction of the Straits, the accumulation of vessels, plying from one bank to the other of the Straits, awaiting a favourable change of wind that would allow them to pass. This tacking about is what the piers would seriously inconvenience. What would become of fishing, and how could the hundreds of fishermen of all nationalities, but for the most part English, French, and Belgian, continue their trade, when they must leave their nets of more than 1,700 yards in length at the mercy of the tide for five or six consecutive hours at the time of the herring season? And for all ships indiscriminately, even for the most powerful steamers, what risks the presence of 72 obstacles would be in foggy, snowy, or squally weather, or if the sea were only what it unfortunately so often is in the Straits, very rough, with choppy and high waves with foaming crests, due to the great shallowness which

greatly inconvenience even the steamers built specially to fight against them.

It must not be forgotten that, if there are more than 100 days of total or partial fog during the year there are many more than 100 days of very rough sea. In addition to which the relative frequency of naval disasters on both sides is proved by the fact that navigation is far from being carried there under normal conditions. The very serious hindrance these piers would cause to the navigation would inevitably awaken the susceptibilities of all nations interested in maritime commerce and consequently in the open sea. That would mean an international question that could only be decided with great difficulty, admitting that it could be settled at all.

Therefore it can be easily understood that the Company for the Bridge over the Channel conceived, perhaps as an alternative, a project allowing the submersion of the bridge, which means its construction at a depth of 48 feet below water, thus forming a roadway for a transporter wagon, the platform of which would emerge above the highest tides, and which could carry four railway trains at once.

Here most important technical objections were raised. The creation of this submarine barrage would certainly alter the course of the currents in the Straits and thereby those along the coasts, the consequences of which it would be impossible to foresee; it would perhaps mean that Dover or Folkestone on the English coast, Boulogne or Calais, and perhaps Dunkerque, on the French, would be irremediably silted up. The result of the slightest change on these shores, the smallest geological irregularities of the bottom on the situation and height of the sandbank spread along the English and French coasts, is too evident to those knowing anything about the Straits to believe in the feasibility of a submarine barrage reducing by more than two-thirds its average cross section.

But this is not all. The preservation of this submarine bridge, which could not be maintained nor even inspected, would be most difficult, if not impossible to hope for. One wonders to what risk of running off the rails the wagon rolling along would be exposed. It is also true that this wagon would have been exposed to meet many other hindrances on its way. Without considering the danger that would arise in case of a drifting wreck becoming entangled in the bridge, there is also the possibility of a ship's anchor let down in rough and stormy weather parting, as even the most solid of anchors have been known to do, at the bottom of the Straits, dashing against the bridge, and obliging the ship to abandon part of its chain, thus forming a most dangerous obstacle. Granted the said wagon were sufficiently elevated and heavy enough not to be displaced by encounter with the waves, what can be said of its chances running foul of any obstacle? Two vessels having a clear course, and capable both of manœuvring properly, very often have difficulty in not fouling each other in the Straits; there are such instances every day. What would it be if some day a wagon unable to perform evolutions were substituted for one of the boats?

With regard to its utility for traffic, all idea of using it for passenger traffic would have to be abandoned. Passengers would avoid sea-sickness but at the cost of considerable loss of time, including that of embarking and landing. A wagon of this sort weighing several thousand tons, with its supports buried in the water, could certainly not be moved quickly by any means; its speed could be inferior to steamers of very moderate speed. Thus the crossing would perhaps take from one and a half to two hours. Besides the loss of time, what dependence could be placed upon the service if two trains could not, under the most favourable conditions, follow each other in the same direction between France and England in less than four hours? There is no doubt at all that this

would be a considerable drawback as compared to the present situation, when there are hourly departures in the morning from England for France and Belgium.

One can understand the authors of this project, having to face such strong objections, going further still in their schemes, and after having submerged their bridge to have abandoned it completely by floating the wagon referred to, that is to say, by substituting simple ferry-boats, examples of which are to be found working everywhere, though in infinitely less difficult circumstances. The case in the Straits is much more complicated on account of the frequency of the heavy swell and of the fall and rise of the tides, attaining sometimes as much as 23 feet. We should travel beyond the boundaries of our object by discussing the scheme of the ferry-boats. They do not appear to meet the same requirements as the tunnel. One scarcely sees the necessity of shipping trains on board ferry-boats simply to save the passengers the trouble of changing with their hand luggage. This scheme appears simply to meet a question of economy for the loading and unloading of merchandise, and this is far from the main idea that has guided all the men who have taken up the tunnel question, the aim of which is to assure a land communication between England and France. Let us hasten to return to it by examining the political, economical, and even military interest that this conception has in these days.

II.

The disappearance of mistrust that existed between both countries, and the evident and indispensable harmony that should exist to the interests of France and England, have recalled to men of progress, on both sides, that a project, already thoroughly studied, had thus been adopted more than twenty years ago by both Governments.

It is to be hoped that the opposition this project met with at one time will prove to have been only accidental. English

opinion, indeed, seems to be changing on this subject, and we could quote numerous articles that have recently appeared in their magazines or reviews, where opinions are very clearly expressed that the tunnel, far from proving a national danger for England, would on the contrary be very advantageous.

It is not on the French side of the Channel, where it is thought that the new situation in Europe can but consolidate the Franco-British union, that the character of a military danger for England will be given to the tunnel.

It is not, however, useless to examine once for all what the past opposition means concerning the English national defence.

The part the tunnel would play in time of war with a Continental Power can be judged in different ways and from very opposite points of view. We said previously that at one time English public opinion had seen in the tunnel a possible means of invasion. For us French people, who have been obliged to study the problems of unexpected transport of troops in case of sudden surprise, the danger of invasion by rail through the tunnel cannot be considered seriously. It is not admissible that an attack like this could be prepared without the invaded Power being put on its guard ; but to us who know by experience, alas ! the difficulties with which embarking is surrounded, and particularly the landing of troops, armaments, and baggage in secrecy, it is known also what impossibilities would encounter the troops which, contrary to all expectation, might have been brought in secrecy to the English end of the tunnel !

It would be sufficient to simply have the tunnel watched by several trustworthy men to ensure the impossibility of any penetration even by a few soldiers only, and two or three explosive mines placed at the head of the tunnel and lighted from a distance would be sufficient to block the end and prevent any outlet on the English side.

But supposing these means of safeguard to be insufficient,

could train-loads of troops be dealt with in England without stations and landing quays prepared in advance ? It would be nothing but confusion, as the disasters during the war of 1870-71 proved to the army of General Bourbaki. The transport of troops by rail is an extremely complicated undertaking. It demands a concentration of men and rolling stock that it is impossible to conceal when it is a question of an important effective force ; it requires security in transport, very easy to destroy in and beyond the tunnel ; it requires a rapid clearance at the arrival platforms impossible to obtain at the English stations that are situated beyond the tunnel and that have not been built for this purpose. The fear that the tunnel would be made use of for the introduction of an invading army is therefore perfectly chimerical.

But if all this be not sufficient or apparently not sufficient, there is still better prevention :

The British authorities of 25 years ago had made conditions (imagining perhaps that they could not be realized) for the building of the tunnel that it should be so constructed as to enable it to be destroyed at will by the guns of the British fleet. The solution to this original problem which *a priori* seems insoluble is found. It consists in making the tunnel under the ground at one or the other of the two maritime cliffs, at an angle accentuated enough to oblige a compulsory continuation of the line above the shore by means of a large horse-shoe viaduct, bringing the railway on to *terra firma* in the open air ; such a viaduct would be a magnificent *point de vue* for tourists, and at the same time the most perfect target imaginable for the guns of the British fleet, and once destroyed it could not possibly be temporarily re-established. Should this be attempted, it could only meet with the same fate as its predecessor.

Does not all this make it clear from a military point of view that England cannot continue to consider the tunnel as a means of future invasion ?

But it is also possible—and several well-informed minds in England have looked at this side of the question—that the tunnel would be a powerful element of success to the British arms in the event of war with any Continental Power other than France, enabling England to forward relief to its allies, or, *vice versa*, to receive it. It is also well known that England draws from the rest of the world enormous quantities of food products and perishable goods in exchange for the products of its extensive industry, but which she could not do without. It has been said—and Englishmen themselves have said it—that they would be obliged in time of war to divert a large portion of their fleet for the protection of their mercantile marine carrying these goods. If England could ensure a constant supply through the tunnel, all war vessels freed from this rôle of naval convoy would become available for war purposes or for chasing the enemy's purveyors and merchant fleet.

The tunnel thus from a military point of view can be compared to a medal with two faces. Either side can be chosen: either it can be absolutely annulled in the most certain, easy, and immediate way, or in time of war it can be utilized as a powerful auxiliary for transporting provisions, thus freeing an important contingent of British naval forces, while permitting the dispatch of reinforcements from either side.

And, after all, was the military question the real motive which absorbed and dominated English opinion when it decided against the tunnel?

Was not this opinion rather based on the fear of reducing the importance of the Navy, and at the same time on prejudices, quite respectable, but which would not hold water if those who are imbued with them were to consider them from a practical and not a sentimental aspect?

Opposition was raised from this last point of view, as has already been said, from most unexpected quarters; it was

a section of the aristocracy, literary and learned men of Great Britain, who considered that England would cease to be an island if it were accessible by even the smallest aperture. As M. Leroy-Beaulieu said in 1883, and as we observed ourselves just now, "it is the literary and philosophical men who were so much against the idea of England ceasing to be isolated, even though in times of peace one could land there without having passed through the trying ordeal of sea-sickness. It seemed to them that if this change took place all their traditions, old customs, their insularity, their originality, and even their freedom would vanish; and the military man followed the philosopher."¹

Far-seeing minds, however, are beginning to realize that it is high time for England to give up these prejudices, and that it is not the invasion by other nations that is to be feared but its own great isolation.

It is indeed true that the English people are isolated in their island formed by geological phenomena at the beginning of the present geological epoch. The eloquence of statistics is necessary to show how great this isolation is from the rest of the Continent. These statistics prove that though the English travel about a good deal in their own country, they cross the Channel with much more difficulty than other nationalities cross their land frontiers.

Within the United Kingdom people make on an average more than thirty journeys a year, whilst within the limits of their respective countries, the Frenchman makes only eleven, the German sixteen, and the Belgian twenty-two. On the other hand, the crossings made by the English to the Continent taken from the different routes, from Southampton to St. Malo in the west, and from Harwich to the Hook of Holland in the east, give a total number of only 1,200,000 per annum, including the return journey; this in relation to the 39,000,000 (in round numbers) inhabitants of Great Britain

¹ *L'Economiste Français*, April 14th, 1883.

↓
no such date for
this journal,
see ~~1883~~
1883

(1903) gives a little less than one journey on the Continent to each thirty inhabitants.

On the other hand, the French, who are said to be so indifferent about travelling, or rather that portion of them residing on the Northern France Railway system, including Paris and beyond, amounting from ten to twelve million inhabitants at the most, exchange with Northern Germany and Belgium (nationalities even less given to travel than the French) more than $3\frac{1}{2}$ million travellers, three times more than the whole of England sends to Continental Europe.

Do not these figures characterize the isolation of the English population, the only possible explanation of which is to be found in the barrier made by the sea?

It seems impossible to us, looking at it from all points of view, either political, social, moral, or economic, that such an isolation can be considered advantageous.

Politically, socially, and morally it is evident that the intercourse of nations by frequent intercommunications must be the most powerful means by which they can know, appreciate, and, by the force of example, perfect one another.

From an economic point of view people are beginning to realize that those nations whose merchants and manufacturers, or their representatives, travel most abroad, are those whose commercial and manufacturing industries develop most. The nation which sends its commercial travellers most about is the one which is surely destined to outrun the others whose representatives remain at home.

The English, however, so to speak, do not go out of their own country. We have said that the number of travellers between England and the Continent does not exceed 1,200,000 a year. Supposing that no foreigner travels to England, it would be at most only 600,000 English who cross every year to the Continent. In reality there are no more than from 400,000 to 500,000, a most insignificant number.

If, on the other hand, we consult statistics, notably the Customs Statistics, for several consecutive years, we ascertain that our business transactions with England do not progress with such rapidity as they do with Belgium, and especially with Germany, that is to say, with those of our neighbours with whom the contact between man and man is more actively developed.

To be convinced, it suffices to compare during an interval of ten years the business transactions between our country and its two great neighbours England and Germany.

It is stated that from 1895 to 1904, the last year the results of which have been published by the French Customs, that the general trade between France and England has increased from 1,915 million francs (£76,600,000) to 2,219 million francs (£88,760,000), an increase of 16 per cent., or on an average 1·6 per cent. per year.

During the same period our trade with Germany has grown from 793 million francs (£31,720,000) to 1,177 million francs (£47,080,000), an increase of 47·5 per cent., or on an average nearly 5 per cent. per year, *three times* more than that with England.

These remarkable figures only confirm the impression we have always had when studying the variations of traffic: the German immediately comes himself as soon as there is likelihood of business to be done; he does not hesitate to travel. Do we not see in summing up these figures the truth of a daily fact, viz., that the number of international journeys from the Northern system from 1904-5 progressed less than 10 per cent. in connection with England, while it has plainly progressed 15 per cent. with Germany?

Without doubt it is the dread of crossing that is the cause, for two reasons: first, because sea-sickness is feared (we have seen sound business men having most important business on hand hesitate about making the journey simply because they were bad sailors); secondly and chiefly, because from the act

of embarking and landing one must resign oneself to passing a sleepless night or else sacrifice a whole or at least half a day to the journey. Either of these two alternatives is often difficult for a business man to face.

This is only truism, which, however, becomes of great importance when the international travellers come to be analyzed. It is certain that no French or Belgian business man would now hesitate, even for a question of relative modest importance, to go to Brussels or Paris, knowing that he can start in the morning, dispose of five or six hours for business either at Paris or Brussels, and return home at night under conditions that allow him to enjoy complete rest and remain in an absolutely normal physical state for continuing his usual duties the next day.

This journey has been made possible on the Northern Railway, first between Paris and several large towns such as Lille, Douai, Arras, Roubaix, Brussels, Antwerp, Liège, etc., and after having rendered it possible it has been made easier by a rather important improvement in the organization of the trains; the result is shown by an increase in the number of travellers, much more important than that which resulted from the reduction of rates, and at the end of a comparatively short time this was succeeded by a corresponding augmentation in the conveyance of goods.

The tunnel would allow this enormous progression of intercourse between Paris and London.

By putting London at five hours distance from Paris the tunnel would do much more than reduce the present quickest route by two hours; it would permit the great step in advance of a departure from either of the two capitals at 8 or 9 a.m. with arrival at the other at 1 or 2 p.m., starting back again at 5 or 6 in the evening to return home between 11 o'clock and midnight.

Thus the train service between the two capitals would after the lapse of a few years be doubled and tripled, and

the flow of business between the two countries would follow accordingly.

These are the practical considerations that should help Englishmen to decide in favour of the tunnel.

No economical question can be feared for England from this tunnel, as it can be positively affirmed that no harm can happen to its mercantile marine.

Even to a superficial analyst it is evident that the relatively high rates that the passage by the tunnel will necessitate could only be afforded by passengers or for the conveyance of articles of great value but of small compass either by express or goods train. As it is, all this class of traffic is almost exclusively in the hands of the railway companies on one side or other of the Channel, and it would be their own steamers, few in number and not remunerative, that would suffer from this diversion of traffic, objections the companies would be the first to make light of, as they would recover by the general growth of traffic what they would lose by their steamers in consequence of the tunnel.

The Englishmen who are well versed in these things have never looked at the question otherwise; we have seen it in the historical account that the Board of Trade (which corresponds in England to our Ministry of Commerce) pronounced in favour of the construction of the tunnel in 1870-1880. And it is, again, the reason why in 1883 one of the men who had the greatest influence on British public opinion, Mr. Bright, the old friend and companion in strife of Cobden, and Mr. Gladstone's old colleague, one of those who have most contributed to lead England into the path of economical reform, made a speech at the Institution of Civil Engineers in London, in which with rare finesse and much judgment he ridiculed the opposition that had just been formulated on the subject of the tunnel. Far from celebrating the silver streak as a national protection of England, he deplored the isolation of his country from the rest of the world, caused by geological disturbance.

Sooner or later these ideas—so true as regards the real and practical interest of England—will appear clearly to the majority. The movement is already beginning, and the time has perhaps arrived to interest the general public in the practical realization of the problem, to acquaint them with a few details of the latest studies of which the Submarine Tunnel has been the object, to show them up to what point these studies have been carried on, and that we are now in the presence of a definite project which can be realized at any moment.

III.

It is more or less well known what difficulties are to be met with in the boring of tunnels of great length, and also the variety of problems that must be solved and the time and money spent before arriving at the completion of such tunnels as the Mount Cenis ($7\frac{1}{2}$ miles), the St. Gothard (9 miles), Arlberg (6 miles), and the Simplon (12 miles). What obstacles would there not be in the boring of a tunnel of not much less than 33 miles?

It is obvious, however, that these difficulties would be quite unlike those met with in the Simplon, the latest achievement—difficulties due to its length, to its low level, and the heat resulting therefrom, the inundations arising from the discovery of hot water springs, and to the nature of the ground. The submarine tunnel will be three times as long as the Simplon, and the necessity of keeping to strata, where infiltration is not to be feared, renders it a somewhat delicate problem. Difficulties would also be met with in the clearing away of the débris, resulting from the great length of the tunnel and the necessity of accomplishing this process by vertical hauling, identical with that used in mines. But, on the other hand, the ground will be much easier to bore and more regular, with practically no infiltration to fear, if the boring be carried

on in the proper strata, while the temperature from the depth of the tunnel (on an average 162 feet below the bottom of the sea) would not differ much from 10 to 12 degrees Centigrade, very near that of water at its maximum of density, i.e. 4 degrees above zero.

It is obvious that if very useful lessons can be learnt from the gigantic work of the boring of existing tunnels and from the remarkable progress obtained in the industry of mines, particularly coal-mines, for the sinking of shafts, piercing of galleries, and the raising of coal and débris to the surface, there would still be some important problems to solve.

The first and certainly the most important of all would be the necessity of working in the impermeable stratum, safe from any infiltration of sea-water. It can safely be said that the whole question of the successful completion of the tunnel lies in this possibility, the rest being accessory.

The first thing to find out, then, is whether this impermeable stratum really exists without a fault, sufficiently thick and regular to allow of the construction of the tunnel.

As has already been stated at the beginning of this article, the studies made before 1875, even those of Thomé de Gamond himself, were not based on strictly scientific and geological examination of the problem. The absolute necessity of establishing the tunnel in certain strata, deposited in a certain geological age, had not been sufficiently taken into consideration. The fixed idea seemed to be that any inflowing of water could be as easily mastered as in an ordinary tunnel. The French Company for the submarine tunnel, founded in 1875, at once realized on the contrary that the construction of the tunnel could only be possible if the strata under the Channel were of a sufficient continuity of hardness and impermeability.

Therefore its first thought has been to obtain the technical information as follows :—

(1) The geological study of the strata appearing on both the English and the French coasts across the whole width of the Straits.

(2) The choice of the geological stratum in which the tunnel should be bored.

(3) The fixing by experiments of the best form of boring operations in this stratum.

When studies were made of geological formations to the north of the Boulonnais (region of Boulogne), including the neighbourhood of Calais, on the one hand, and that of Kent on the other, it was impossible not to be struck by the complete parallelism of these two formations as regards the strata which starts with Jurassic at the base and finishes with the Tertiary. The consecutive order of the geological strata, the structure of each layer, as much as regards its nature as the geological irregularities of which it has been the subject after its formation, and prehistoric flora and fauna, all are identical and seem to show that the two beds are portions of a country that was formerly continuous. The two cliffs, English and French, two great sections of ground worthy of a museum, appear almost as reproductions of each other; one would think they were two proofs of the same negative. It seems as if it has only depended on the chance of human events that we have not on the cliff of Cape Blanc Nez the counterpart of Dover Castle and the cliff with all its Shakespearian memories. Further on at Folkestone, tamer and less tragic in its memories, we find the replica of our Griz Nez cliffs and the east side of Kent in the neighbourhood of Deal runs parallel with the plains of Calais, while the beautiful roadstead of Dunkerque and the sandbanks constituting the "Riden" on our French coast are a continuation of the Goodwin Sands sheltering the roadstead of the Downs, hardly less renowned in history.

Between these two great witnesses of geological identity of the English and French soils, what mystery does the sea

hide from us with regard to the nature of the bottom of the Straits? Should we be right in considering the Straits as a simple furrow hollowed in the ground, or else compare it, on the contrary, to the results ensuing from the huge stroke of an axe cutting through the continuity of ground, imposing on the Company the most formidable task of working towards the unknown under the sea?

That is the first question the Company had to solve, and thanks to the admirable work undertaken on its account by a mission composed of two distinguished geological Engineers, MM. Potier and A. de Lapparent, and thanks also to the strength of the tides, which keep the bottom of the Straits in a good condition of cleanliness, undisturbed, except in a few places, by any deposit of sand, mud, or shells, this question has been solved in a most complete way.

In 1876 and 1877 MM. Potier and A. de Lapparent took more than 7,000 soundings in the Straits, not only ordinary soundings for discovering the depth of the water, but those in which the sounding lead was replaced by a sharp-angled tube charged with a sufficiently heavy weight, so that in falling to the bottom of the sea the tube was enabled to bring away a sample of it, a 'carrot' to use a technical term, two or three inches long, sufficient in most cases to allow of geologically identifying the ground from which the sample had been obtained.

Thanks to these soundings, 3,000 of which are geologically accurate, MM. Potier and A. de Lapparent have been able to continue the geological chart under the Straits with a precision almost as great as their English and French colleagues had displayed in making geological maps of English and French soil. The contours of these charts, showing the evenness of the different varieties of ground, are found to be continuous without any flaw or break right across the Straits. The consecutive order of the strata is reproduced throughout; even the depth of the different layers met with is shown to be

relatively constant. In a word, all the stated facts only confirm the supposition that the Straits have been hollowed at a comparatively recent period, and going back to the beginning of the present geological epoch were caused by powerful erosions and not by a breaking up of the ground.

Now it has been proved that amongst the geological strata of

Jurassic,

Wealden

Albian (Gault or Upper Greensand)

Cenomanian (Lower Chalk)

Turonian (Middle Chalk)

Senonian (Upper Chalk)

} Cretaceous,

which are found in regular order, and form the upper bed of the Cretaceous system, without faults, is one, the Cenomanian, commonly called the Grey Chalk of Rouen (*craie grise de Rouen*), the study of which in the cliffs on both sides and in the numerous wells that had been sunk made it seem particularly suitable for the passage of the tunnel on account of its homogeneity, complete absence of cracks, perfect impermeability, and firmness that would allow of comparatively easy working. It is this stratum, averaging a depth of about 65 yards, that the geological studies, as they progressed, have shown more and more clearly to be the best in every way for the proposed works. It was in it that the direct experiment of submarine boring was tried and continued until March, 1883, by the French Company under the direction of the eminent director of works Mr. L. Breton, who is as equally illustrious as a geologist as in the working of mines, and from whom it can be said that the geological formation in the region of Boulogne holds no secret.

The direct experiments in this layer consisted in sinking on the shore at Sangatte a shaft to the depth of about 65 yards below sea-level and of great diameter, and in starting

from the bottom of this shaft a gallery to be used for experimental purposes $2\frac{1}{4}$ yards in diameter, penetrating the before-mentioned layer of Cenomanian Chalk for a distance of 1 mile 250 yards under the sea.

This gallery proved, on the one hand, the almost perfect impermeability of the stratum, and on the other the possibility of continuing the boring with a gradual increase of speed until 410 yards a month is attained—an increase that would certainly be exceeded if Colonel Beaumont's drilling machine were used, an auger, which hollows out the chalk by a movement of continuous rotation, identically the same as that used for the piercing of hard wood.

As we mentioned at the beginning of this report, similar studies and experiments were made in England by the South-Eastern and Submarine Railway Companies, which led exactly to the same conclusions as to the existence of this Cenomanian stratum, its thickness, hardness, impermeability, and the possibility of its safe working.

Added to this, the conscientious studies made by Mr. L. Breton since 1879, more than 25 years ago, in the region of Boulogne and in Kent still further confirm these results. They have proved that the layers of chalk exist without dislocation or out-throw, and have revealed largely curved bends without a break.

On the occasion of these studies, new examinations have been made recently by Mr. G. F. Dollfus, one of the principal contributors to the geological map of France. They deal with a certain number of soundings made at different times on both sides of the Straits, either in search of coal or for other objects. Mr. Dollfus stated at the meeting of the Geological Society of France, November 19th, 1906, that whenever these soundings took place the Cenomanian stratum was identical in structure and thickness, without the slightest variation, and that consequently if it is possible to go through this bed for the whole way without being obliged to pass

through another, it can certainly be reckoned that the Tunnel can be bored without any risk of surprise.

It is also the decided opinion of English geologists, and one of the most eminent, Sir Archibald Geikie, told us so recently, confirming the quasi-certitude of previsions made in 1876 and 1877 by MM. Potier and A. de Lapparent, that the bed of Cenomanian Chalk was quite regular and even across the whole width of the Straits, and that he did not anticipate any trouble in this direction.

The choice of a hard, continuous, and impermeable bed of sufficient thickness being settled, how can the tunnel be bored in this layer, which seems placed there ready by nature to show us the means of re-establishing the land communication which formerly existed between England and France?

The cross section of the tunnel itself should next be decided. Should it be a single tunnel containing both tracks, or, rather, should it be composed of two distinct tunnels, one for each track?

The latter solution is recommended as the more prudent. In fact, all over the Straits a minimum thickness of 44 to 55 yards of the impermeable chalk can be counted upon, and there is every reason to believe that this expectation will be realized; but even with such a thickness it would perhaps not be very wise to drive a double track tunnel, which would necessarily be oval, from 30 to 33 feet wide and 20 to 23 feet high. We should thus have in the Grey Chalk an arch, above which there would remain a bed the thickness of which would be rather uncertain and could not be more than a few yards, while it would possibly have to undergo a relatively considerable pressure, since that pressure might attain to 200 or 300 lbs. per square inch. To adopt such a solution would certainly involve some risk, and it would be infinitely preferable to construct two parallel circular tunnels, having each from 18 to 20 feet in diameter, separated by a distance of 17 yards, not reacting, therefore

on each other as regards the resistance of the bed, but minimizing the cause of dislocation, thanks to their circular shape, which is unquestionably the best as far as resistance to inside and outside pressure is concerned. The two tunnels would communicate by means of transversal galleries very near to each other, every 110 yards for instance, thus keeping the two tunnels in close connection with each other. The cross section of the tunnels being thus definitely arrived at, it is necessary to choose between two solutions: either to provide for the draining of infiltration waters through the main tunnels, or to place the water-draining gallery quite apart therefrom.

The first solution presents one great disadvantage: it would necessitate the adoption of a saddle-shaped section for the longitudinal section of the tunnel; this means that the tunnel would have its highest point in the centre of the Straits with its two lowest points on the coast in order to collect the infiltrated water at the two points from where it would have to be pumped out and thrown again into the sea. It is also from these two low points that the tunnel would emerge. This would mean elongation of the line, and give rise to gradients which would reach the maximum possible with the electric traction that would certainly be adopted.

Such an inconvenience would suffice to reject *a priori* the first solution; and it is for this reason that Mr. L. Breton did not hesitate to recommend and adopt the second solution, viz. a draining gallery quite independent of the tunnel itself. This solution would be all the more justified as the draining gallery would at the same time be used to construct the tunnel and carry away the débris. From this point of view the consideration of the length of time necessary for the carrying out of the work prohibits the adoption of the first solution, in which but a single opening could be provided at each side of the Straits, starting from the low points situated on the shores. The length of time required would

therefore depend on the speed of boring a double gallery of the maximum section, that is to say, that the works would have to be carried out experimentally, since information at hand at the present time apply only to a gallery having 2 yds. 1 ft. 8 ins. diameter, viz. $4\frac{1}{4}$ square yards section in round numbers, while the boring of a double gallery having a section nearly ten times larger would have to be faced.

It is on account of the above reasons that the first solution should be rejected and the second adopted, a solution in which the longitudinal section with its lowest points on the shore will be reserved for a special gallery used first for the boring and then for the draining of infiltrated water during the whole period of working of the line ; for both these uses it will suffice to provide for a section about as large again as that of the known and already tested gallery, bringing it to about 10 feet diameter in round numbers. When once the shafts have been sunk it is from the lowest points of this gallery that the work would be begun. With the exception of the first few miles of the tunnel bored from the shafts already sunk as starting-points, it will be from this gallery that cross branches of the same section will be driven to join the alignment of the main tunnel, from various points of which the work will be started so as to construct the permanent tunnel by successive sections meeting one another underneath the sea.

We will deal further on with the conditions of this work.

When, owing to the provision of a special gallery, the tunnel is freed from the necessity of drainage, it will only keep its saddle-shaped section for a few miles in its central part ; it will then proceed by increasing declivities, ranging doubtless from 0 to $\frac{3}{4}$ inch per yard.

We therefore have now sufficient data as far as cross and longitudinal sections of the tunnel are concerned.

We also know that the work will be started through the draining gallery, which will also serve as a driving

gallery ; we know that this draining gallery will start from the lowest point under the solid ground where the infiltration water will be collected at the end of the shaft or shafts, and through which will be carried away debris and water during the construction of the tunnel, and through which also will be continued the exhaustion of infiltration water during the working of the line.

The longitudinal section that should be given to the draining gallery is perfectly known and fixed by Mr. Breton's very ingenious studies, which may be summed up as follows :—

Supposing we proceed with the draining gallery already constructed from the centre of the tunnel, in this central and elevated part, the amount of infiltrated water to be disposed of would perforce be *nil*. If we admit that the amount of water penetrating into the tunnel is invariable in each yard of the gallery, the nearer we approach the French coast the more infiltration water must be drained, increasing proportionally in quantity according as the distance increases from the middle of the Straits. Therefore the draining gallery should have an increasing discharging capacity, which will reach its maximum when we arrive at its termination at the lowest points of the shaft, where the water will be collected and taken up to the surface. Now what is the discharging capacity of any gallery? That capacity depends firstly on the section of the gallery and secondly on its declivity. To change the section of our gallery is practically impossible, because it will probably be bored by means of a drilling machine more or less similar to Colonel Beaumont's, giving invariable circular section from one end to the other ; and further, because during the tunnelling it will be used for the carrying away of the *débris* ; this would require a minimum section for the passing of workmen and locomotives, a section which will be about the same as the one made by the drill. It is therefore on the second factor, i.e. that of declivity, that we must depend

as much as is necessary in order to increase the discharging capacity of the draining gallery. This will therefore start from the point where it will leave the tunnel at a slight declivity of 1 in 2,000, which will increase gradually to its maximum of about 1 in 50 when arriving at the lowest points.

This determination being arrived at would certainly result in the laying out of the gallery in plan, could we but know with absolute certainty the form of the Grey Chalk bed in which the line should be maintained. Leaving the alignment of the tunnel within $1\frac{1}{2}$ miles from the central point of the Straits, the gallery would go further and further away from it in proportion as the level of the tunnel and the level of the gallery differed, the gallery sinking and the tunnel rising. In order to admit of this divergence of levels we should have to avail ourselves of the general declivity of the beds to the north, the alignment of the gallery would thus bear more and more to the north, while that of the tunnel would be directed more to the south.

Not knowing with absolute certainty the position of the underground strata, the drainage gallery would have amongst other advantages that of allowing it to be tested. As concerns the choice of location for the boring of the shafts in the ground, the facilities required for this boring should first be taken into consideration. The difficulty will be to avoid as much as possible the superficial sand bed on which the village of Sangatte rests. These shafts should be bored to the bottom of the Grey Chalk; then the thickness of the chalk should be ascertained at the chosen boring points. The boring should then go on according to the theoretical direction of the draining gallery, and as soon as 110 or 164 yards of gallery have been made, i.e. after about one week's work, a boring above and below should be made in the chalk in order to ascertain the exact position of the gallery in the bed. A week later similar borings should be made and repeated every week, that

is to say, every 130 to 164 yards. When any of these consecutive borings show that the gallery is getting too near to either the upper or lower limits of the chalk bed, indicating that the bed has not the exact formation hypothetically attributed to it, the alignment would have to be modified accordingly without altering the theoretical section in order to come back to the general position which it is important to keep. The drainage gallery would thus become more or less sinuous. But this is of little importance. It would not hinder the flow of water, nor would it interfere with the free passage to the gallery of the small electric trains which would be used to remove rubbish and for the conveyance of the men.

Before beginning to drive the tunnel proper the character of the stratum will thus have been ascertained, and inspection will be continued through every cross branch which, as the driving of the gallery goes on, will lead towards the line of the permanent tunnel, thus determining by successive tests each intermediate point, so that the tunnel may be exactly at the right depth to secure a good section.

How many intermediate branches, therefore, will be necessary? That is to say, how many separate intermediate starting-points must be attacked? This question may be said to depend upon the maximum lapse of time fixed for the carrying out of the works. From the data we have at hand at the present time, data which the progress of science and notably the use of electricity can only render more favourable, it is not out of the way to hope that the drainage gallery may be driven at an average rate of about 22 yards per day, that is to say, 131 yards per week or 4 miles per annum.

It is therefore theoretically after four years and a half that it will reach the point where the central part of the tunnel begins, namely, at $15\frac{1}{2}$ or 16 miles in round figures from the station of Wissant on the French coast.

If, thanks to acquired experience, we suppose that the tunnel according to its definitive section will be driven at a rate of speed of not less than one-third of that reckoned for the drainage gallery itself, it will take one year in round figures to reach the central point of the tunnel.

Meanwhile we shall, as the draining gallery is continued, have started the above-mentioned branches proceeding to the definitive alignment of the tunnel, and from each end of those branches have started the boring of the tunnel, advancing always according to its definitive alignment and section. The number of these intermediate branches will vary according to the rate of speed taken in the boring of the tunnel at its definitive section. Thus seven branches will be necessary in case (under the worst supposable conditions) the driving of the tunnel is carried on at the rate of $5\frac{1}{2}$ yards per day only, say a quarter of the time used for the drainage gallery ; six will be required if that speed is $7\frac{1}{2}$ yards, and only four if it is 11 yards ; but in any case, thanks to those branches and the driving of the tunnel through several simultaneous openings, it may be stated that the speed of completion of the tunnel is practically independent of the time it will take to bore it ; that it depends only on the speed of driving the drainage gallery, and that, after the experiments carried out by Colonel Beaumont's machine, it will very probably take $4\frac{1}{2}$ to 5 years to drive the tunnel, starting from the moment of the boring of the first shaft of the draining gallery, that is to say, from $6\frac{1}{2}$ to 7 years in all.

This process of carrying out the work by means of intermediate branches, so advantageous as far as driving in the chalk bed and quickness of work are concerned, will present many problems rather interesting to solve. That of transport, for instance, which will have to be carried on through the drainage gallery ; removal of *débris*, conveyance of the workmen and machinery ; all these will have to take place inside the gallery by means of a small

underground 2 feet gauge electric railway, which, in the most active period of its traffic, will have to carry away not less than 4,000 tons of rubbish per day, representing about 100 trains a day in each direction, added to the conveyance of at least 1,200 people corresponding to the return journeys of the workmen and staff from the several opening points. This staff will be divided into three, most probably four, gangs, so as to secure the continuity of the work: 1,200 people and 4,000 tons of rubbish per day, covering an average distance of $6\frac{1}{4}$ miles, represent a traffic which many railways of local or even general interest would envy.

This will not exceed its limit of capacity, but it will certainly, including as it does the hoisting of men and rubbish, present a working problem of great intensity and of no small interest to solve.

Thus, thanks to the scientific progress made in the last twenty years, to the improvements which will no doubt be made in the drilling machines, thanks to the utilization of electric traction for the removal of rubbish, to the use of high speed rotary pumps driven by electricity for the exhaustion of infiltration water collected into the shafts; thanks also to minor progress such as the use of the telephone and electric light, the boring of the tunnel and draining gallery will not take more than from $4\frac{1}{4}$ to 5 years after the completion of the auxiliary and preliminary works, the most important of which will be the laying of tracks to carry away the rubbish and the boring of large diameter shafts similar to colliery shafts.

On the French shore the boring of shafts will be one of the difficulties to be met with by the Engineers superintending the works in charge.

These difficulties will be minimised by choosing a place outside the Quaternary sands which cover the chalk and by using the same methods for piercing the chalk which proved so satisfactory to Mr. L. Breton when boring the shafts. At

all events, it will be possible, as foreseen by Mr. Breton, to have recourse to congelation and perhaps to cementation. Those borings will not be very expensive, since they will not require more than from one to two million francs (£40,000 to £80,000), but they will take a long time, not less perhaps than two years.

At the same time, as the sinking of the necessary shafts is taking place, in spite of the fact that the two existing shafts will be utilized, it will be necessary to lay tracks to carry away the rubbish; this would be done by laying a special temporary line and also putting in the definitive junction line which will connect the tunnel to the existing railway from Calais to Boulogne.

Regarding junction lines, recent studies have shown that the route sketched out in 1881 could be notably improved.

That alignment, starting from Calais and following the shore up to Wissant, described a very long curve and finally entered the tunnel near Strouanne; this meant a course of $12\frac{1}{2}$ miles to be added to the journey from Boulogne to Calais for the transit from Paris to London.

Instead of that considerable detour, and owing to the new point chosen to enter the tunnel, a little to the south of Cran d'Ecalles, the junction will branch off at Beuvrequent, pass very near Marquise, and end almost on a straight line at Wissant, where the Custom House office and sorting station would be established, and where the change of engine will take place, the electric engine proceeding to the siding, and the steam-engine for hauling the train to Paris being simply attached to the tail of the train, which thus becomes the head without any shunting or loss of time.

The part of the line in the open will not be of a difficult or expensive nature, except the viaduct, which will precede the entrance to the tunnel, and which, in order to meet British military objections, may possibly be established so as to be within reach of the fire of a fleet commanding the Straits.

That part would have a length of $8\frac{3}{4}$ miles only ; its gradients would not exceed 1 in 160. So that, in the direction of Paris, one would never meet the long gradients of 1 in 125 which are now experienced on the line from Boulogne to Calais beginning at the gradient of Caffiers.

Regarding expense, the substitution of a length of $8\frac{3}{4}$ miles instead of $20\frac{1}{2}$ will save nearly four million francs. Regarding the time from Paris to London, the saving will be far greater, inasmuch as 20 miles will be saved, corresponding to a reduction in the gradient of two millimetres per metre, say 1 in 500. This would mean a great advantage.

Regarding connections with Belgium and Germany, the position would hardly be changed. At any rate, it would be easy, when so desired, to replace the junction line to Calais necessary for the trains going to and from that point by a branch line of about five miles direct from Wissant, and which, through a tunnel of $1\frac{1}{2}$ miles only near Wadenthum, would emerge near Pihen on the line from Boulogne to Calais, thus saving to the trains from Germany, Belgium, etc., the detour through Marquise.

In short, the progress made by science and industry since the interruption of the tunnel works, more particularly as regards the use of electric traction, and the results of recent studies both on the formation of the strata to be traversed and on the location of junction lines and approaches of the tunnel, will certainly allow the time necessary for the completion of the tunnel to be reduced to seven or eight years, and save a very considerable amount of money as compared with the expense calculated at the start. At any rate, this progress should convince us that not only is the work of the submarine tunnel a realizable, but even a relatively easy one, and that it may be carried out with the fullest confidence in ultimate success.

IV.

It now remains to give some data concerning the commercial aspect of the enterprise and the nature and importance of the traffic it would have to meet. Unquestionably, this point is a very delicate one, upon which it is perhaps more difficult to express an opinion than it is on the technical point.

However, a short examination and a few figures may give some idea of the considerable interest that the enterprise presents.

In the present state of things, relations between England and the Continent are, as previously explained, very little developed, so far as passenger traffic is concerned. Not more than 1,200,000 passengers in round numbers travel by all the competing routes, although there are on the one hand a population of 39,000,000 inhabitants in Great Britain, and on the other hand a Continental population of over 100,000,000, taking only France, Italy, and Central Europe into account. It is unquestionably to the fear of "crossing the water" that this small exchange of traffic is due, inasmuch as between France, representing in round figures 40,000,000 inhabitants, and Belgium, representing with her neighbours Holland and the northern part of Germany served by the Cologne railroad, about 50,000,000 inhabitants, the number of annual passengers exceeds 4,000,000.

Let us suppose that, as by a fairy wand, the tunnel were established to-morrow. What attractive effect would it exercise on the 1,200,000 passengers? The attraction would be the greatest on the sea-routes which, used at the present time, are the nearest to the tunnel; it is obvious that the tunnel would take up almost all the passengers on the lines from Boulogne and from Calais; but it is possible that it may take up but few passengers from the Southampton to

Project adopted on the 30th May, 1876, by the International Commission of the Submarine Railway "to serve as a basis for the Treaty to be concluded between France and England concerning the Channel Tunnel and submarine enterprise."

Projet adopté le 30 mai 1876 par la Commission Internationale du Chemin de Fer sous-marin "Pour servir de base au traité à conclure entre la France et l'Angleterre relativement à l'entreprise du Tunnel et du Chemin de fer sous-marin."

THE undersigned, the Commissioners appointed by the Governments of Great Britain and France to consider the conditions upon which the two Governments should, by means of a Treaty for that purpose, come to an understanding with respect to the proposed Tunnel and Submarine Railway, met at Paris from the 29th of January to the 5th of February, and at London from the 22nd to the 30th of May, 1876. After having considered and discussed the various questions to be dealt with in connection with this enterprise, they submit to the two Governments the accompanying Memorandum, which they recommend should be adopted as the basis of the proposed Treaty between Great Britain and France with regard to the said Tunnel and Railway.

H. W. TYLER.
C. M. KENNEDY.
HORACE WATSON.
CH. GAVARD.
C. KLEITZ.
A. DE LAPPARENT.

LES Commissaires soussignés, nommés par les Gouvernements de France et de la Grande Bretagne pour examiner à quelles conditions les deux Puissances pourraient s'entendre, par le moyen d'un Traité spécial, relativement au projet de Tunnel et de Chemin de Fer Sous-marin, se sont réunis à Paris du 25 janvier au 5 février, et à Londres du 22 au 30 Mai, 1876.

Après avoir examiné et discuté les diverses questions qui se rattachent à cette entreprise, ils viennent soumettre aux deux Gouvernements le projet ci-joint qu'ils proposent pour servir de base au Traité à conclure entre la France et l'Angleterre relativement à l'entreprise du Tunnel et du Chemin de Fer Sous-marin.

(Signé)

CH. GAVARD.
C. KLEITZ.
A. DE LAPPARENT.
H. W. TYLER.
C. M. KENNEDY.
HORACE WATSON.

Memorandum.

1. The boundary between England and France in the tunnel shall be half-way between low-water mark (above the tunnel) on the coast of England, and low-water

Projet.

1. La frontière entre l'Angleterre et la France dans le tunnel sera fixée au milieu de la distance séparant la ligne des basses eaux (au-dessus du tunnel), sur la côte

that friendly intercourse so essential to maintain the equilibrium of European Powers, and with it the peace of the world.

It is only to be hoped that British public opinion of to-day is more enlightened than it was twenty-five years ago on the true position of this great question, and that at last in the course of a few years willing men on both sides of the Channel may be able to meet in the middle of the Straits, 110 yards below the average sea-level, to seal by a fraternal embrace the sympathy of two peoples made to understand and help each other.



APPENDIX.

St. Malo line. Between these two extreme points all those intermediate would be grouped.

For instance, if it is admitted that there will be

90 per cent. of passengers *vid* Calais and Boulogne,

70 „ of passengers *vid* Dieppe,

50 „ only of passengers *vid* Ostend,

20 „ of passengers *vid* Flushing, and

5 „ only of passengers from the other routes,

there would be at once a *clientèle* of 900,000 passengers for the tunnel.

But supposing, however, that instead of the tunnel being completed in one day, its construction was only decided upon to-morrow, it would only be after six years, or more likely seven years, that the line could be worked. Then, the importance of traffic would show an increase. From what we learn by past statistics, the progress is 50,000 passengers per annum in round numbers; therefore the present 900,000 passengers would in seven years number 1,200,000.

This is a minimum. It is quite certain that the existence of land communication would raise the traffic between England and France to a more normal rate, nearer to the one we find between France and Belgium. While not expecting, during the first year of the working, that we should get a traffic that would give us not only 1,200,000 but from 5,000,000 to 6,000,000 passengers, still there is no doubt that the reality would range between these two extreme figures, approaching the second one within a few years.

So far as goods traffic is concerned, the *clientèle* of the tunnel has been valued at very different figures, ranging from 1,500,000 tons (figure given in 1883) to 5,500,000 tons (figure given in 1889).

It is extremely difficult to give an accurate opinion on this point. It is certain, however, that should the tunnel exist, it would secure the traffic of the 600,000,000 francs (£24,000,000) of high-priced articles quoted in the 1902 Custom Statistics and

taxed *ad valorem*. The tunnel could also rely upon a minimum of 50,000 to 60,000 tons sent by express goods train. But what about those by goods trains? Doubtless it would take up only a small part of the latter, leaving the greater portion to the sea route, where the freights are low. Its only traffic, so far as slow goods train is concerned, would no doubt be limited to goods of the so named "first class" and perhaps some of the "second class." * At any rate, it is obvious that, taking into consideration the increased traffic resulting from time and the development of relations between the two countries, traffic cannot fail to be considerable.

At all events, it is certain that both as regards passengers and goods the tunnel will be remunerative; but it is equally true that, at least at the beginning, the traffic will by no means be an extremely heavy one.

Taking into consideration the inequality of traffic in both directions, which never balance each other at any time, also the variation in traffic from one time to the other in course of the year, it may be reckoned that at the most 20 to 30 passenger trains and 30 to 40 goods trains will go through the tunnel every day altogether.

These figures, of course, correspond to the working of a moderate traffic, which we quote only to show that there is a considerable margin so far as the capacity of the tunnel is concerned, and that the fears expressed by some optimists as to the possibility of conveying all the traffic offered are fanciful.

CONCLUSION.

In concluding, it may be said that there can be no possible doubt as to the technical success of the enterprise, or as to the economic advantages it would bring to the commerce and industry of both countries, and also in helping to develop

* Fifth and fourth class English classification.

mark (above the tunnel) on the coast of France. The said boundary shall be ascertained and marked out under the direction of the International Commission to be appointed, as mentioned in Article 4, before the Submarine Railway is opened for public traffic. The definition of boundary provided for by this article shall have reference to the Tunnel and Submarine Railway only, and shall not in any way affect any question of the nationality of, or any rights of navigation, fishing, anchoring, or other rights in, the sea above the Tunnel, or elsewhere than in the Tunnel itself.

2. The French section of the Submarine Railway shall be constructed, maintained, and worked in conformity with the French laws and with that of the 2nd August, 1875, in particular, subject to the provisions of the Treaty to be concluded between the two Governments. The English section of the Submarine Railway shall, subject to the provisions of the Treaty to be concluded between the two Governments, be constructed, maintained, and worked in accordance with such conditions as Her Majesty may by Order in Council hereafter impose in connection with the undertaking of the said Company (as specified in the Channel Tunnel Company, Limited, Act, 1875), with such, if any, modifications as may hereafter be made by Act of Parliament.

3. Within five years from the 2nd of August, 1875, the French Company shall be bound to conclude an agreement in writing with an English Company, and reciprocally the English Company shall be bound to conclude an agreement in writing with a French Company, with a view to the construction, maintenance, and working of the Submarine Railway.

This term "Submarine Railway" applies throughout the present

d'Angleterre, de la ligne des basses eaux (au-dessus du tunnel) sur la côte de France. Avant la mise en exploitation du Chemin de Fer Sous-marin, la susdite frontière sera déterminée et tracée sous la direction de la Commission Internationale qui sera instituée ainsi qu'il est dit à l'Article 4. La définition de frontière faisant l'objet du présent Article s'appliquera uniquement au Tunnel et au Chemin de Fer Sous-marin ; elle n'aura aucun effet relativement aux questions de nationalité, de droits de navigation, de pêche, et d'ancrage ou autres droits sur la mer au-dessus du tunnel ou ailleurs que dans le tunnel même.

2. La section Française du Chemin de Fer Sous-marin sera construite, entretenue, et exploitée conformément aux lois Françaises, et notamment à celle du 2 Août, 1875, sous réserve des dispositions du Traité à conclure entre les deux Gouvernements. La section Anglaise du Chemin de Fer Sous-marin sera, sous réserve des dispositions du Traité à conclure entre les deux Gouvernements, construite, entretenue, et exploitée conformément aux conditions que Sa Majesté pourra, dans la suite par un Ordre en Conseil (by order in Council) imposer relativement à l'entreprise de la dite Compagnie (comme cela est spécifié dans "The Channel Tunnel Company, Limited, Act, 1875"), avec toutes les modifications qui pourront y être introduites ultérieurement par Acte du Parlement.

3. Dans un délai de cinq ans à partir du 2 Août, 1875, la Compagnie Française sera tenue de passer un contrat avec une Compagnie Anglaise et réciproquement, la Compagnie Anglaise sera tenue de passer un contrat avec une Compagnie Française en vue d'exécuter, d'entretenir, et d'exploiter le Chemin de Fer Sous-marin.

Cette dénomination de Chemin de Fer Sous-marin s'applique, dans

Protocol to the Tunnel, to the Railway, and to all the works connected therewith, such railway being bounded in France by its junction with the railway from Boulogne to Calais, and in England by its junctions with the South-Eastern and London, Chatham and Dover Railways.

This term does not include the works mentioned hereafter in Article 16.

4. There shall be constituted an International Commission to consist of six members, three of whom shall be nominated by the British Government and three by the French Government.

The International Commission shall advise the two Governments on all questions relating to the construction, the maintenance, and the working of the Submarine Railway, and shall have power, on giving notice to the respective Companies, to make such inspections as they consider necessary, and the Companies shall be bound in every way to facilitate such inspections, and to cause their delegates to be present.

Each Company shall render annually to its Government an account of its receipts and expenses in such form as the Governments shall approve, after hearing the International Commission, and shall, if required, afford to its Government the necessary facilities for comparing such accounts with the books of the Company.

If at any time any difference shall arise between the two Companies as regards the construction, maintenance, or working of the Submarine Railway, such difference shall be settled by the two Governments after having taken the opinion of the International Commission, subject to such legal actions as the Companies may bring in conformity with the Conventions concluded between them and with the legislation of the two countries.

tout le présent Protocole, au Tunnel, à la ligne et à tous les ouvrages et immeubles qui en dépendent, la dite ligne ayant pour limites, en France, sa jonction avec le Chemin de Fer de Boulogne à Calais, et en Angleterre, ses jonctions avec les Chemins de Fer South-Eastern et London, Chatham, and Dover.

Cette dénomination ne comprend pas les travaux mentionnés à l'Article 16 ci-après.

4. Il sera institué une Commission Internationale composée de six membres, dont trois seront nommés par le Gouvernement Anglais, et trois par le Gouvernement Français.

La Commission Internationale donnera *son avis* aux deux Gouvernements sur toutes les questions relatives à la construction, à l'entretien, et à l'exploitation du Chemin de Fer Sous-marin. Elle aura le droit, en donnant avis aux Compagnies respectives, de faire toutes les inspections qu'elle jugera convenables, et les Compagnies devront faciliter ces inspections de toutes manières et s'y faire représenter par des délégués.

Chaque Compagnie présentera à son Gouvernement un compte annuel de ses recettes et de ses dépenses, sous la forme qui sera approuvée par les Gouvernements, la Commission Internationale entendue ; et, si elle en est requise, elle devra fournir à son Gouvernement les facilités nécessaires pour la comparaison de ces comptes avec les livres de la Compagnie.

Toute difficulté entre les deux Compagnies, relativement à la construction, à l'entretien, et à l'exploitation du Chemin de Fer Sous-marin, sera tranchée par les deux Gouvernements, sur l'avis de la Commission Internationale, sous la réserve des actions juridiques que les Compagnies pourraient exercer conformément aux Conventions conclues entre elles et à la législation des deux Etats.

tion of the International Commission.

11. Each Company may, at any time during the construction of the works, abandon its concession, on proving to the satisfaction of its Government the impossibility of continuing the said works.

In such case, forfeiture shall be declared and enforced according to the provisions of the Law granting the concession in France or of the Act of Parliament in Great Britain.

12. At any time after the end of thirty years from the opening of the Submarine Railway, each Government shall have the right to purchase the undertaking of the Company established on its territory. This right shall not, however, be exercised excepting after a joint agreement between the two Governments, and after six calendar months notice in writing has been given to the Companies. In the event of purchase, the rights of each Government in and over the soil, works, and undertaking shall be limited to its own territory, as defined in Article 1.

13. The amount of the purchase-money in each country shall be determined as follows, under the supervision of the International Commission :—The net receipts of the Company during the seven years immediately preceding the year in which the purchase is effected shall be ascertained ; the two years of minimum receipts shall be excluded, and the mean of the annual net receipts during the other five years shall be taken. That mean net receipt will form the amount of an annuity to be payable to the Company for the unexpired term of the concession, or, at the option of the British Government, for the purchase of the English concession, the basis of the calculation of a capital sum representing the value of the annuity at the time of purchase. In any case the

l'avis de la Commission Internationale.

11. Chaque Compagnie pourra, à toute époque, durant l'exécution des travaux, renoncer au bénéfice de la concession, dans le cas où l'impossibilité de continuer les dits travaux serait dûment constatée par le Gouvernement dont elle relève.

Dans ce cas, la déchéance sera prononcée, et il sera procédé conformément aux stipulations de la Loi de Concession Française ou de l'Acte du Parlement Britannique.

12. A toute époque après la trentième année à partir de la mise en exploitation du Chemin de Fer Sous-marin, chaque Gouvernement aura le droit de racheter l'entreprise de la Compagnie établie sur son territoire. Toutefois ce droit ne pourra être exercé que d'un commun accord entre les deux Gouvernements, et après un avis donné par écrit aux Compagnies six mois pleins d'avance. En cas de rachat, le droit de chaque Gouvernement sur le sol, les travaux, et l'entreprise, sera limité à ce qui existera sur son propre territoire, comme il est défini à l'Article 1.

13. Le prix de rachat dans chaque pays sera déterminé de la manière suivante, sous le contrôle de la Commission Internationale : On relèvera les recettes nettes obtenues par chaque Compagnie pendant les sept années qui auront précédé celle où le rachat sera effectué ; on en déduira les produits nets des deux plus faibles années, et l'on établira le produit net moyen des cinq autres années. Ce produit net moyen formera le montant d'une annuité qui sera payée à la Compagnie pendant chacune des années restant à courir sur la durée de la concession ; ou, au choix du Gouvernement Anglais, pour le rachat de la concession Anglaise, ce produit moyen formera la base du calcul d'un capital représentant la valeur de la dite annuité au moment du rachat. En aucun cas,

amount of the annuity to be so payable, or which is to form the basis of such calculation as aforesaid, is not to be less than the amount of the net receipts during the year immediately preceding the year of purchase.

Each Government is to provide and pay the annuity or capital sum which will be due to the Company established on its territory.

The Company shall receive, in addition, the payments to which they may be entitled at the date fixed for the expiration of the concession in accordance with paragraph 4 of Article 8.

14. The working and maintenance of the Submarine Railway after either the purchase or the termination, or the forfeiture, of the concession in either country, shall be provided for by a Supplementary Convention then to be made between the two Governments.

15. Each Government shall have the right to suspend the working of the Submarine Railway and the passage through the Tunnel whenever such Government shall, in the interest of its own country, think necessary to do so. And each Government shall have power, to be exercised if and when such Government may deem it necessary, to damage or destroy the works of the Tunnel or Submarine Railway, or any part of them, in the territory of such Government, and also to flood the Tunnel with water. If any of the powers of this Article are exercised by either of the Governments, then and in every such case neither the other Government nor either of the Companies shall have any claim to any other indemnity or compensation than the following : If any such power is exercised during the term and currency of the concession to either Company, the period of concession to such Company is to be extended for a term equal to that during which the working of the Submarine Railway has been suspended in consequence of the exercise of any

le montant de l'annuité ainsi payable ou devant former la base du calcul ci-dessus indiqué, ne devra être inférieur au montant des produits nets de l'année qui aura précédé immédiatement celle du rachat.

Chaque Gouvernement devra pourvoir au paiement de l'annuité qui sera due à la Compagnie établie sur son territoire.

La Compagnie recevra, en outre, les remboursements auxquels elle aurait droit à l'époque fixée pour l'expiration de la concession, selon le paragraphe 4 de l'Article 8.

14. Lors du rachat, de l'expiration ou de la déchéance de la concession dans chaque pays, l'exploitation et l'entretien du Chemin de Fer Sous-marin seront assurés par une Convention Supplémentaire à intervenir entre les deux Gouvernements.

15. Chaque Gouvernement aura le droit de suspendre l'exploitation du Chemin de Fer Sous-marin et le passage à travers le Tunnel, quand il jugera convenable de le faire dans l'intérêt de son propre pays. Chaque Gouvernement aura aussi le droit pour l'exercer quand il le jugera nécessaire, d'endommager ou de détruire en totalité ou en partie les travaux du Tunnel ou du Chemin de Fer Sous-marin sur son propre territoire, comme aussi de noyer le Tunnel. Dans le cas de la mise à exécution par l'un des Gouvernements de l'un des droits mentionnés dans le présent Article, l'autre Gouvernement et aucune des deux Compagnies ne pourront prétendre à d'autre indemnité ou compensation que la suivante : Si le droit susdit est exercé durant la période de concession faite à l'une des deux Compagnies, le terme de la concession faite à cette Compagnie sera prorogé d'une période égale à celle pendant laquelle l'exploitation du Chemin de Fer Sous-marin aura été suspendue en conséquence de l'exercice de l'un quel-

shall be bound, at the request of the Company established in its own country, to take all the above-mentioned objects at a valuation, which shall be made in such manner as may be provided by the laws of the country ; and reciprocally, if the Government requires it, the Company shall be bound to give up, under the same conditions, the rolling stock and other things above mentioned.

The Government, however, will only be bound to take over the stores necessary for working the railway for six months from the end of the concession.

9. The works of exploration shall be commenced within one year from the 1st July, 1876.

If within five years from the 2nd of August, 1875, the concessionnaires have not been able to conclude the agreement referred to in Article 3, or if, in consequence of the result of the borings and other preparatory works, they recognize the impossibility of carrying out the undertaking, the Companies shall have the right of abandoning the concessions.

Within five years from the 2nd of August, 1875, each Company is to declare to its own Government whether such Company proposes to retain the concession. This period of five years can, however, on the application of the Company, be extended in either country by the Government, at its discretion, for three further years, that is to say, for eight years from the 2nd August, 1875.

In default of such declaration having been made by either Company within the above periods, and also if either Company should declare its intention of abandoning the undertaking, the concession to the Company making such default or declaration shall be considered as null and void ; and action shall be taken in accordance with the provisions of Article 10. If one of

stations, chaque Gouvernement sera tenu, sur la demande de la Compagnie établie sur son territoire, d'acquérir les objets ci-dessus désignés, suivant une évaluation qui sera faite conformément aux lois du pays ; et, réciproquement, si le Gouvernement le demande, la Compagnie sera tenue de livrer, dans les mêmes conditions, le matériel roulant et autres objets ci-dessus désignés.

Toutefois, le Gouvernement ne sera tenu d'acquérir que les approvisionnements nécessaires pour l'exploitation pendant six mois, à partir de l'expiration de la concession.

9. Les travaux d'explorations devront être commencés dans un délai d'un an à partir du 1^{er} juillet, 1876.

Si, dans un délai de cinq ans à partir du 2 Août, 1875, les concessionnaires n'ont pu réussir à passer le contrat mentionné dans l'Article 3, ou si, par suite du résultat des sondages et autres travaux préparatoires, ils reconnaissent l'impossibilité de donner suite à l'entreprise, les Compagnies auront le droit de renoncer aux concessions.

Dans un délai de cinq ans à dater du 2 Août, 1875, chaque Compagnie devra déclarer à son Gouvernement si elle a l'intention de conserver la concession. Ce délai de cinq ans pourra néanmoins sur la demande de la Compagnie et si le Gouvernement le juge convenable, être prorogé, dans chaque pays, de trois années, ce qui portera sa durée totale à huit années à partir du 2 Août, 1875.

Faute par l'une ou l'autre Compagnie d'avoir fait la déclaration dans le délai ci-dessus mentionné, et aussi dans le cas où l'une ou l'autre des Compagnies déclarerait qu'elle a l'intention d'abandonner l'entreprise, la concession accordée à la Compagnie qui se serait placée dans l'un de ces deux cas sera considérée comme nulle et non avenue, et il sera procédé conformément

the two Companies abandon its concession, the two Governments shall consult as to the measures to be adopted, without the other Company being entitled to raise any objection or to lay claim to any indemnity.

Twenty years, to date from the day on which the Company shall declare its intention to retain the concession, shall be allowed for the completion of the Submarine Railway and the opening of the said railway for public traffic.

10. At the expiration of each of the periods mentioned in the preceding Article, the Companies shall cease to have the right to commence or to execute the works which should have been commenced or executed within the period which has so expired, and if at any time after the works have been commenced the Companies shall for a period of one year, without such cause as the respective Governments, after hearing the International Commission, may consider reasonable, cease to carry on the works, and if the Submarine Railway be not opened for public traffic before the expiration of the period of twenty years mentioned in the preceding Article, or if at any time the Companies, without such cause as the respective Governments, after hearing the International Commission, may consider reasonable, cease for a period of six months to work the Submarine Railway, in conformity with the rules laid down by their Governments, then, and in any of such cases, the concessions granted to the Company in fault shall be liable to forfeiture, which forfeiture shall be enforced according to the laws for the time being of each country respectively.

The forfeiture can only be pronounced by a Government against a Company after the necessity of that forfeiture has been recognized by the joint agreement of the two Governments on the recommenda-

aux dispositions de l'Article 10. Si une seule des deux Compagnies renonce à la concession les deux Gouvernements aviseront aux mesures à prendre sans que l'autre Compagnie soit admise à élever aucune réclamation ni à prétendre à aucune indemnité.

Vingt ans, à partir du moment où la Compagnie aura déclaré vouloir conserver la concession, seront accordés pour l'achèvement du Chemin de Fer Sous-marin, et la mise en exploitation du dit Chemin de Fer.

10. A l'expiration de chacun des termes mentionnés dans l'Article précédent, les Compagnies cesseront d'avoir le droit de commencer ou d'exécuter les travaux qui auraient dû être commencés ou exécutés dans la période expirée ; et, à toute époque après le commencement des travaux, si les Compagnies cessent, pendant une période d'un an, sans un motif jugé valable par les Gouvernements respectifs, la Commission Internationale entendue, de poursuivre les travaux, et si le Chemin de Fer Sous-marin n'est pas mis en exploitation avant l'expiration de la période de vingt années mentionnée dans l'Article précédent, ou si, à toute époque, les Compagnies, sans un motif jugé valable par les Gouvernements respectifs, la Commission Internationale entendue, cessent, pendant une période de six mois, d'exploiter le Chemin de Fer Sous-marin, conformément aux règles prescrites par ces Gouvernements ; alors, et dans un quelconque de ces cas, celle des Compagnies qui aura été en faute encourra la déchéance, et il sera procédé à cette déchéance suivant la législation en vigueur à ce moment dans chaque pays.

La déchéance ne pourra être prononcée par un Gouvernement contre une Compagnie, que lorsque la nécessité de cette mesure aura été reconnue d'un commun accord par les deux Gouvernements, sur

The Commission shall meet at all times when it shall consider it convenient to do so, and at least twice in each year. It shall also meet at any time at the request of either Government. But no meeting shall be valid unless there be present at least two members appointed by each Government. If at any meeting of the International Commission the members present of the one nationality shall differ in opinion from the members present of the other nationality, reference shall be made to the respective Governments.

The International Commission shall report every year to the respective Governments, both upon its own proceedings and upon questions connected with the Submarine Railway. It shall, moreover, submit to the two Governments its proposals for Supplementary Conventions with respect—

(a) To the apprehension and trial of alleged criminals for offences committed in the Tunnel or in trains which have passed through it, and the summoning of witnesses.

(b) To Customs, police, and postal arrangements, and other matters which it may be found convenient so to deal with.

5. On the completion of the Submarine Railway, the International Commission shall cause it to be inspected as they may see fit on behalf of the two Governments, and after such inspection, and on receiving from the International Commission their recommendation in writing, but not before, the Submarine Railway shall be opened for traffic.

6. One set of regulations shall be applicable to the Submarine Railway as a whole; the regulations to be subject to the approval of the two Governments on the recommendation of the International Commission; the tariff of maximum charges shall be fixed in accordance with the Tariff hereto annexed.

La Commission se réunira, toutes les fois qu'elle le jugera convenable, et au moins deux fois par an. Elle se réunira aussi à toute époque, à la demande de l'un ou l'autre des Gouvernements. Mais elle ne pourra délibérer valablement qu'autant que deux membres, au moins, de chaque nationalité seront présents. Si, à une réunion de la Commission Internationale, les membres présents d'une nationalité sont d'une opinion contraire à celle des membres présents de l'autre nationalité, il en sera référé aux Gouvernements respectifs.

La Commission fera, chaque année, un rapport aux deux Gouvernements, tant sur ses propres travaux que sur les questions qui se rattachent au Chemin de Fer Sous-marin. Elle soumettra, d'ailleurs, aux deux Gouvernements ses propositions pour des Conventions supplémentaires relatives—

(a) A l'arrestation et au jugement des accusés pour délits commis, soit dans le tunnel, soit dans des trains y ayant circulé, et à la citation des témoins.

(b) Aux dispositions de douanes, police, et postes, et autres matières que l'on jugera utile de traiter.

5. Après l'achèvement du Chemin de Fer Sous-marin, la Commission Internationale fera procéder de la manière qu'elle jugera convenable, et au nom des Gouvernements, à l'inspection du Chemin de Fer Sous-marin. Après cette inspection et sur la remise d'un avis favorable de la dite Commission, consigné par écrit, et non auparavant, le Chemin de Fer Sous-marin pourra être livré à l'exploitation.

6. Une série de règlements devra être appliquée au Chemin de Fer Sous-marin dans son ensemble. Les règlements devront être approuvés par les deux Gouvernements sur l'avis de la Commission Internationale. Le maximum des prix sera déterminé conformément au tarif ci-joint.

7. Each Company shall be responsible for keeping in good and substantial repair the portion of the Submarine Railway situated within its own country ; and in case of default, the two Governments, on the recommendation of the International Commission, shall have power, each in its own country, to execute, as may seem right, all necessary works and repairs. The two Governments shall also have power, each in its own country, to receive all moneys payable to the Companies, until the expenses of such works and repairs are covered. These moneys shall be collected in each country in accordance with the existing laws.

8. The concession granted by each Government shall be for a term of ninety-nine years from the opening of the Submarine Railway. At the date fixed for the termination of the concession, or at an earlier period, in the event of the forfeiture of the concession, pronounced in the manner laid down in Article 10 below, each Government shall become possessed of all the rights of the Company, established on its territory, in and over to the Submarine Railway in such country, and shall enter immediately into enjoyment of all the revenues of the Company.

The Company, in each country, shall be bound to hand over to the Government in a good state of repair the portion of the Submarine Railway in such country.

During the five years preceding the date fixed for the end of concession, the Government of each country shall have the right to receive the revenues of the Company established in its own country, in order to apply them to the maintenance of the said portion, unless the Company takes steps to carry out this engagement fully and entirely.

With regard to the rolling stock, movables, and stores of all kinds, the furniture and tools of workshops and stations, each Government

7. Chaque Compagnie sera responsable du maintien en bon état d'entretien de la portion du Chemin de Fer Sous-marin située dans son propre pays, et, à son défaut, les Gouvernements, sur l'avis de la Commission Internationale, auront le pouvoir, chacun dans leur pays, d'exécuter, comme ils le jugeront convenable, tous les travaux et réparations nécessaires. Ils auront également le droit, chacun dans leur pays, de percevoir toutes sommes payables entre les mains des Compagnies respectives, jusqu'à concurrence des dépenses des dits travaux et réparations. Cette perception se fera, dans chaque pays, conformément aux lois existantes.

8. La concession sera accordée par chaque Gouvernement pour une période de 99 ans, à partir de la mise en exploitation du Chemin de Fer Sous-marin. A la date fixée pour l'expiration de la concession, prononcée dans les formes prescrites par l'Article 10 ci-après, chacun des Gouvernements sera mis en possession de tous les droits que la Compagnie établie sur son territoire possède sur le Chemin de Fer Sous-marin dans ce pays, et entrera immédiatement en jouissance de tous les revenus de la Compagnie.

La Compagnie, dans chaque pays, sera tenue de livrer au Gouvernement, en bon état d'entretien, la portion du Chemin de Fer Sous-marin située dans ce pays.

Dans les cinq années qui précéderont la date fixée pour l'expiration de la concession, le Gouvernement de chaque pays aura le droit de percevoir les revenus de la portion du Chemin de Fer Sous-marin dans son pays pour les appliquer à l'entretien de la dite portion, si la Compagnie ne se mettait pas en mesure de satisfaire pleinement et entièrement à cette obligation.

Quant au matériel roulant, au mobilier et aux approvisionnements de toute nature, aux appareils et outils garnissant les ateliers et les

of the powers mentioned in this Article. If any such power is exercised before the expiration of the period during which the French Government has engaged not to grant any rival concession, the term of this period shall be extended in like manner as that of the concession.

Each Government, however, reserves to itself the right, if it should think fit, to grant to the Company established in its own country, but not to the Company established in the other country, such compensation for damage actually done by its order to the works of each Company as such Government may in its discretion think proper.

16. Works for purposes of defence, and such other works as may be required by either Government, shall be executed by each Company in accordance with the laws for the time being in force in the country where such Company is established.

17. It is understood, as regards the use of the Submarine Railway, that equal facilities shall be afforded in the formation of trains, in the running of carriages and waggons, and in the transport of passengers, animals, and goods of every description, whatever may be the points of departure or of destination, and whatever may be the routes followed.

18. The provisions of the Treaty to be concluded shall not come into force before they have been sanctioned by the Legislatures of the two countries.

conque des droits mentionnés dans cet Article. Si le même droit est exercé avant l'expiration de la période pendant laquelle le Gouvernement Français s'est engagé à n'accorder aucune concession concurrente, le terme de cette période sera prorogé comme celui de la concession.

Chaque Gouvernement se réserve d'ailleurs le droit d'accorder, s'il le juge à propos, à la Compagnie établie dans son pays, mais non à la Compagnie établie dans l'autre pays, les compensations qui lui sembleront convenables pour les dommages causés par son ordre aux travaux de cette Compagnie.

16. Les travaux défensifs ou autres demandés par l'un des deux Gouvernements seront exécutés par les Compagnies respectives, en conformité des lois existant dans chaque pays à l'époque de leur exécution.

17. Il est entendu, en ce qui concerne le service du Chemin de Fer Sous-marin, que les mêmes facilités seront accordées, soit dans la formation des trains, soit pour la circulation des voitures et des wagons, soit pour le transport des voyageurs, des animaux et des marchandises de toute nature, quels que soient les points de départ ou de destination et quelles que soient les routes suivies.

18. Les dispositions du Traité à conclure n'entreront en vigueur qu'après qu'elles auront été sanctionnées par les Législatures respectives des deux pays.

C. K.
H. W. T.
H. W.

A. DE L.
CH. G.
C. M. K.

C. M. K.
CH. G.
A. DE L.

H. W. T.
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